Comparison Between Absolute Orientation Determination Methods of Doubly Rotated Blanks

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***Abstract*—In this paper, comparison between absolute orientation determination methods of doubly rotated blanks is given. To measure doubly rotated cut, classical goniometers need several manipulations of the blanks (for example 90° shift rotation) and they are often achieved manually inducing imprecision. Furthermore, a reference baseline in the sample is necessary to know the final cut angles. With the presented method, the blank is measured without any manipulation and no reference is needed. It is possible to define any orientation from the X-ray diffraction positions from two or three different atomic planes. With this method, the orientation of the resonator, which already machined into a circular shape are also easily measurable.**

Keywords—Cut orientation, Crystal, X-ray, Bragg method

I. INTRODUCTION

The orientation and characterization of single crystals remain in recent discussions [1]. Measurement by X-rays has been the focus of significant effort [2-4] and has been highly motivated by industrial applications demanding high precision process and quality control. This kind of measurement is generally the direct application of the Bragg's law. The RX tube is fixed, the crystal is mobile around the axis of the device. Diffraction occurs when the atomic planes are under Bragg incidence θ_B. The diffracted beam then makes an angle of $2\theta_B$ with the direct beam. To measure doubly rotated cut, classical goniometers need several manipulations of the blanks (for example 90° shift rotation) and they are often achieved manually inducing imprecision. Furthermore, a reference baseline in the sample is necessary to know the final cut angles. In the laboratory universal system, the blank is measured without any manipulation and no reference is needed. It is possible to define any orientation from the X-ray diffraction positions from two or three different atomic planes. With this method, the orientation of the resonator, which already machined into a circular shape are also easily measurable.

II. MEASURMENT METHOD

The entire definition for measuring the normal to the surface of the sample $\overrightarrow{N_g}$ is possible from the trihedron obtained from the vectors perpendicular to these three lattice planes $\overrightarrow{N_\iota}$. Knowing the angles (ρ_1, ρ_2, ρ_2) as defined in Fig. 1a, it is then possible to determine the orientation of the blank by the two angles (φ, θ) defined by the IEEE standard (Fig. 1b) . Fig. 2 recalls the Bragg principle and presents the device.

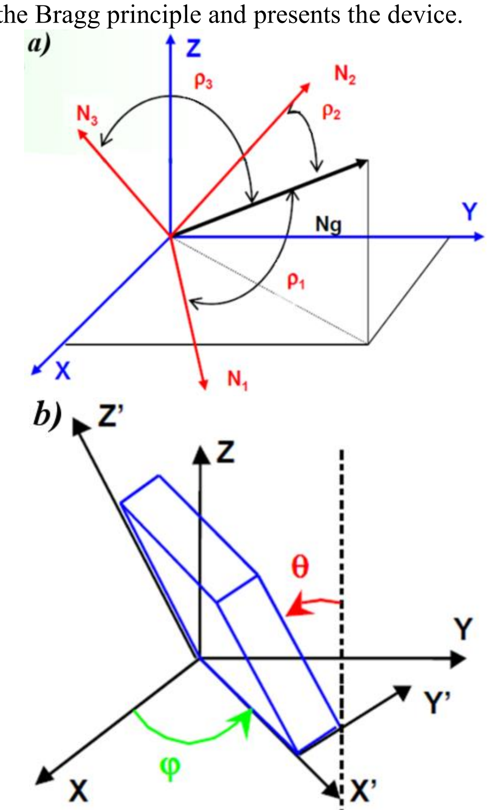

Fig. 1. The normal $\overrightarrow{\mathbf{N_g}}$ of a blank can be oriented according atomic planes defined by $\overrightarrow{\mathbf{N_i}}$. b) Definition of a doubly rotate blank in IEEE standard [5].

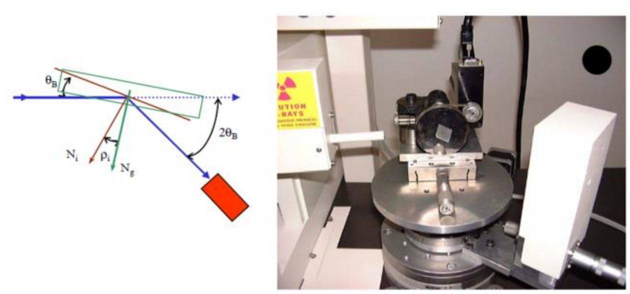

Fig. 2. Bragg principle and the implemented devices.

		SC-cut n°1		SC-cut n°2		SC-cut n°3		SC-cut n°4		SC-cut n°5		Mean	
		θ	ϕ	θ	ϕ	θ	ϕ	θ	ϕ	θ	ϕ	θ	ϕ
3 plans Method	°	34.026	22.193	33.940	21.994	33.936	22.019	33.935	21.990	33.955	21.972	33.958	22.034
	° min s	34 1 34	22 11 35	33 56 24	21 59 38	33 56 10	22 1 8	33 56 6	21 59 24	33 57 18	21 58 19	33 57 30	22 2 1
2 plans Method	°	33.980	22.188	33.823	21.904	33.815	21.957	34.035	21.923	34.020	21.828	33.935	21.960
	° min s	33 58 48	22 11 18	33 49 23	21 54 14	33 48 54	21 57 25	34 2 6	21 55 23	34 1 12	21 49 41	33 56 5	21 57 36
Reference	°	33.970	22.166	33.795	21.958	33.792	21.959	34.002	21.873	34.015	21.909	33.915	21.973
	° min s	33 58 12	22 9 58	33 47 42	21 57 29	33 47 31	21 57 32	34 0 7	21 52 23	34 0 54	21 54 32	33 54 53	21 58 23
3p-2p	°	0.046	0.005	0.117	0.090	0.121	0.062	-0.100	0.067	-0.065	0.144	0.024	0.074
	° min s	**0 2 46**	**0 0 17**	**0 7 1**	**0 5 24**	**0 7 16**	**0 3 43**	**0 -5 -60**	**0 4 1**	**0 -3 -54**	**0 8 38**	**0 1 26**	**0 4 25**
3p-ref	°	0.056	0.027	0.145	0.036	0.144	0.060	-0.067	0.117	-0.060	0.063	0.044	0.061
	° min s	**0 3 22**	**0 1 37**	**0 8 42**	**0 2 10**	**0 8 38**	**0 3 36**	**0 -4 -1**	**0 7 1**	**0 -3 -36**	**0 3 47**	**0 2 37**	**0 3 38**
2p-ref	°	0.010	0.022	0.028	-0.054	0.023	-0.002	0.033	0.050	0.005	-0.081	0.020	-0.013
	° min s	**0 0 36**	**0 1 20**	**0 1 41**	**0 -3 -14**	**0 1 23**	**0 0 -7**	**0 1 59**	**0 2 60**	**0 0 18**	**0 -4 -52**	**0 1 11**	**0 0 -47**

TABLE I. COMPARISON BETWEEN REFERENCE, 2 PLANS AND 3 PLANS METHODS FOR FIVE BLANKS.

For the set of 3 lattice planes has influence on the angles determination [6], the choice of this experimental coordinate system is critical. Every quartz crystallographic plane is not always available for the measures, so we must choose the $\overrightarrow{N_\iota}$.among a subset of planes which satisfy the three following conditions. The planes must be spaced enough for the Bragg reflection to occur (i.e. $h^2 + hk + k^2 \leq \frac{3}{4}(\frac{4\,a^2}{\lambda^2} - l^2\frac{a^2}{c^2})$ where h,k,l are Miller's indices, a and c the size of the quartz primitive cell, and λ the wave length we use); the reflection of the beam must come out of the crystal ($\rho_i < \theta_{B_i}$); and $2 \times \theta_B$must be smaller than our sensor's range of detection. Theoretically more than one hundred planes meet these requirements for both SC and AT blanks according to our predictions with a wave length of 1.5405A.

Among those, we selected 3 planes (043), (-252) and (-244), which we use for the 3p-method. When we already know approximatively the cut angles of a blank, one of the three measures may become useless, because the two first measures give us two cone intersections between which we choose the closest to the orientation we thought it should be. Some planes then can make the calculation even easier, for example the planes (6 0 0) and (-3 6 0), which we use for the 2p-method.

III. RESULT ANS DISCUSSION

As the easiest way to present this comparison, we apply three and two angle methods around the classical angles of the SC-cut quartz crystal. Table 1 gives the first results for five blanks. The mean values are given in the last two rows. The 2p and ref method are closer than the 3p method. The reason for that may be due to the fact that our 3 planes make with each other a lower angle compared the angle between (6 0 0) and (-3 6 0), which are perpendicular, so they make a better "coordinate system" [6].

The precision of the absolute final orientation determinations of these doubly rotation-cuts would be proved by the achievement of resonators from this set of blanks, and the measure of their thermal frequency drift.

IV. CONCLUSIONS

This method allows us to determinate the orientation of any quartz blank, with good repeatability. The two plans method is really quickly, and manages to find θ with good accuracy. The three plan method is more adapted to have an idea of the cut kind. This method is well done for unknown cut, for the 2 plans method requires a hypothesis on the orientation.

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